Treatment and Disposal of Sewage in the National Parks*

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SINCE 1922, sanitary engineers of the U. S. Public Health Service have been detailed to the National Park Service to assist superintendents of national parks, custodians of national monuments, and engineers of the Park Service on problems of sanitation in the parks and at monuments. The work of the sanitary engineers has included surveys and reports of investigations of water supplies, sewerage and sewage disposal, garbage disposal, swimming pools, mosquito control, and general inspections of all places handling and serving food products. In addition, plans have been prepared for water supply systems, sewage treatment plants, and garbage incinerators.

The sewage treatment plants discussed in this paper have been constructed in the parks in the Western Division of the National Park Service. In this division, which includes the National Parks west of the Mississippi River, except Hot Springs National Park, Arkansas, there are 19 parks located as follows: 1 in Alaska, 1 in Arizona, 4 in California, 2 in Colorado, 1 in the Hawaiian Islands, 1 in Montana, 1 in New Mexico, 1 in Oregon, 1 in Oklahoma, 1 in South Dakota, 2 in Utah, 1 in Washington, and 2 in Wyoming. All, except Hawaii, are located in sections or at elevations where there are more or less severe winters. Some are practically inaccessible in winter, others are visited by parties on snow shoes or skis, and 10, which include Carlsbad Caverns, General Grant, Grand Canyon (South Rim), Hawaii, Mount Rainier, Platt, Rocky Mountain, Sequoia, Yosemite, and Zion, are open to tourists by train or automobile throughout the year.

In 1933, the number of visitors was 2,013,024. The maximum number visiting one park was 296,088 at Yosemite, and the smallest, 368, at Mount McKinley. The parks having over 100,000 visitors were: Yosemite, 296,088; Rocky Mountain, 291,934; Hawaii, 237,690; Platt, 220,606; Mount Rainier, 170,104; Yellowstone, 161,938; Sequoia, 126,464; and Grand Canyon, 105,475. There is in addition to the visitors a permanent population which varies from a few in the smaller and less patronized parks to approximately 1,500 in Yellowstone.

The accommodations for visitors in the parks are hotels, lodges, housekeeping cabins, and automobile camp grounds, and for the permanent population residences and dormitories. The locations of these accommodations in

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the various parks vary widely. At the South Rim of the Grand Canyon practically all the visitors and employees live in one area, whereas in Yellowstone there is 1 area with all the accommodations listed above, 4 with all the accommodations except residences, 2 other places with lodges, housekeeping cabins, and large camp grounds, and several other smaller areas having automobile camps. The maximum number of people in one area in a park was 23,000 in Yosemite Valley on July 4, 1932. In Yellowstone there are 6 areas where the total population will vary from 100 to 2,500 people, and other places, mostly automobile camps, where the number of tourists will range from 25 to 100. In Yosemite Valley there were at one time 9,000 visitors living in tents in tourist camps, and in Yellowstone 800 in each of 2 camps.

There are in the western parks, 65 areas having for visitors extensive accommodations which are generally grouped together and served by a common water supply system, sewerage system and disposal plant, garbage incinerator, and other public utilities.

There have been constructed 52 sewage treatment plants since 1922. In designing these plants the important considerations were: (1) protection of streams against contamination and in one park reclamation of sewage for industrial purposes; (2) prevention of odor nuisances; and (3) maintaining architectural and landscape values. The treatment plants constructed include (a) activated sludge, rapid sand filter and disinfection; (b) activated sludge and disinfection; (c) settling tanks and disinfection; (d) settling tanks and spraying systems which distribute settled sewage, with and without disinfection, over natural ground surfaces, usually hillsides of porous material; (e) settling tanks and sub-surface galleries with concrete, wood, or metal walls and covers; (f) settling tank and glass-covered sand filter; (g) settling tanks and open trenches; and (h) settling tanks, broad irrigation, ponds and disinfection. Following are descriptions of a representative plant of each of the types listed above.

ACTIVATED SLUDGE, RAPID SAND FILTER AND DISINFECTION

The cost of hauling water to the South Rim of the Grand Canyon National Park in tank cars and delivering it in service lines, prior to 1932 was \$3.07 per 1,000 gallons and approximately \$2.50 for pumping and delivery since that date. In order to reduce the volume of water hauled, a pressure sand filter was added in 1913 to an existing sewage treatment plant, consisting of septic tank and contact filter, to produce an effluent which could be used in place of fresh water for irrigation of lawns and making steam. For a few years following 1913 the effluent was apparently satisfactory for the purposes noted, but with an increasing volume of sewage the plant became badly overloaded, a serious odor nuisance developed, and the effluent could not be used on lawns because of the odors, or in boilers due to foaming.

It was decided in 1926 to build a new sewage treatment plant to produce an effluent which could be used for industrial purposes and be distributed in a separate piping system properly protected against cross-connections, without being a serious health hazard to the visitors and people living at the South Rim.

A treatment plant consisting of settling tank, slow sand filters, and disinfection seemed to have the most inherent advantages from the standpoint of high removal of bacteria and quality of effluent in general, and low cost of operation and maintenance, but it was impracticable to build this type of plant on account of the high cost of sand delivered to the South Rim. The

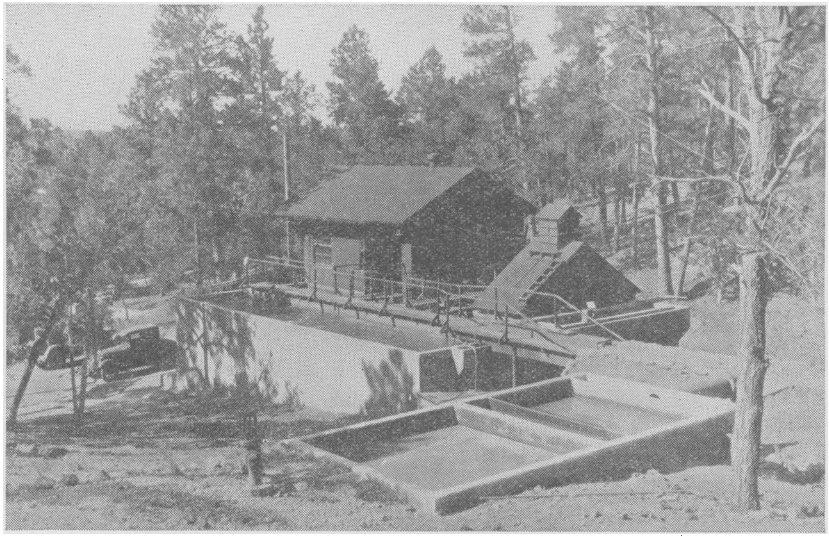

FIGURE I—Sewage Treatment Plant, Grand Canyon National Park

treatment plant designed included activated sludge, rapid sand filters, and disinfection.[1, 2] The local conditions, other than those pertaining to the industrial uses of the reclaimed sewage, which had to be given consideration in the design of the treatment plant, were the variations in the temperature of the raw sewage, from 92° F. in summer to 72° F. in winter, and the treatment of the laundry wastes, which constitute approximately 10 per cent of the total volume. Figure I shows a general view of the treatment plant.

The available data indicated that the maximum volume of sewage produced at the Canyon during 1926 was 100,000 gal. per day, and the treatment plant was designed to treat 200,000 gal. The following devices were included in the plant:

Screen—The screen is 3′ wide by 3′ deep and has ⅜″ by 2″ rectangular iron bars spaced 2⅜″ on centers.

Pre-settling tank—This tank is 16′ by 8′, with an effective depth of 5′ to the top of the two hoppers which are 4′ deep. The theoretical detention period is 30 minutes for a maximum volume of 200,000 gal. of sewage per day.

Diversion chamber—This is a small tank located on the pipe line from the pre-settling tank to the aeration tanks. It receives the activated sludge returned from the clarifier to the aeration tanks and can be used for by-passing the sewage around the plant.

Aeration tanks—There are two of these tanks, each 42′ by 8′ by 10′ deep below the water level. They were designed for an average aeration period of 6 hours.

In each tank there are two continuous concrete channels each 42′ long and having at the top porous plates which rest on T-irons across the channels and in recesses along the sides of the channels, and which are held in place by cement grout. There are concrete ridges between the channels. The air is pumped through 4″ pipes to one end of the channels, and at the opposite end there are 4″ outlet pipes which permit flushing of the channels and cleaning the under surfaces of the porous plates with water or steam. The tanks were designed so that they can be operated in series or separately.

Clarifier—This tank is 16′ square with an effective depth of 11½′. It has a settling rate of practically 800 gal. per sq. ft. per day, and a theoretical detention period of 2 hours when sewage is flowing through at a rate of 200,000 gal. per 24 hours. The influent enters the tank through 4 openings spaced equidistant along one side and 1′ below the water surface, and the effluent flows over a brass weir the full width of the tank. There are inlet and outlet baffles extending 3′ below the water level. The activated sludge moved by the scrapers of the clarifier to the center of the tank is returned to the aeration tanks by an air lift.

Coagulation tank—This tank, originally designed as a coagulation basin to be used in connection with operation of the rapid sand filter, is 16′ by 4′ by 10′ deep. Up to the present time, the filters have operated satisfactorily without the use of coagulants and this tank has been used as a secondary settling tank.

Rapid sand filters—There are 2 of these filters each having an area of 77 sq. ft. The wash-water troughs are of concrete and the underdrainage consists of 12″ headers with 1¼″ cast iron laterals having ¼″ holes bored on 3″ centers. Each filter has 20″ of graded gravel and 32″ of sand with an effective size of 0.40 mm. and a uniformity coefficient of 1.6. Reclaimed sewage, disinfected, is used for washing the filters.

Disinfecting equipment — Duplicate semi-automatic chlorine machines are used for disinfecting the effluent from the sand filters.

Blowers—Two blowers each with a capacity of 225 cu. ft. of free air per minute against 6½ lb. pressure per sq. in. at an altitude of 6,500′, supply the aeration tanks and air lift with air.

TABLE I

B. COLI IN RECLAIMED SEWAGE, GRAND CANYON NATIONAL PARK

Year	Source	No. samples tested for B. coli	No. samples having 3 or more 10 c.c. portions positive	Per cent samples having 3 or more 10 c.c. portions positive	No. 10 c.c. portions tested for B. coli	No. 10 c.c. portions positive	Per cent 10 c.c. portions positive
1929	Storage tank *	40	0	0	225	13	5.8
	Power house †	39	0	0	218	10	4.6
	Total	79	0	0	443	23	5.2
1930	Storage tank	87	1	1.2	435	21	4.8
	Power house	90	0	0	450	29	6.4
	Total	177	1	0.56	885	50	5.6
1931	Storage tank	54	0	0	270	15	5.5
	Power house	60	1	1.7	300	19	6.3
	Total	114	1	0.88	570	34	5.9
1932	Storage tank	73	0	0	365	21	5.8
	Power house	47	0	0	235	8	3.4
	Total	120	0	0	600	29	4.8
1933	Storage tank	40	1	2.5	200	10	5.0

* Tank located 1½ miles from treatment plant and has capacity of 200,000 gal.
† Samples collected from make-up tank which receives reclaimed sewage from storage tank.

TABLE II

CHEMICAL ANALYSES OF RAW AND RECLAIMED SEWAGE
GRAND CANYON NATIONAL PARK

Month 1933 1934	Suspended matter p.p.m.			Settleable solid c.c. per liter 1 hour		Dissolved oxygen p.p.m.		Oxygen demand p.p.m.			Soap hardness p.p.m.		Hydrogen ion concentration		
	R	C	C. W.	R	C	C. W.	P. H.	C	C. W.	P. H.	R	C. W.	R	C	C. W.
January	104	10.0	0.3	8	0.3	7.3	8.2	6.8	1.8	1.5	21.0	14.8	7.6	7.2	7.5
February	74	10.0	0.3	6	0.25	7.4	8.5	7.3	1.6	1.4	25.0	16.6	7.5	7.2	7.4
March	111	9.0	0.3	9	0.24	7.3	8.3	7.2	1.3	1.3	21.7	17.7	7.5	7.1	7.3
April	91	10.0	0.3	7	0.28	7.0	8.0	6.8	1.3	1.2	21.3	19.2	7.5	7.2	7.4
May	103	11.0	0.3	8	0.29	6.7	7.3	6.3	1.6	1.6	20.0	20.8	7.5	7.2	7.4
June	163	9.0	0.3	10	0.24	5.6	6.0	5.3	1.3	1.4	22.7	15.9	7.5	7.2	7.3
July	105	11.0	0.3	8	0.3	4.5	5.2	4.3	2.5	1.8	20.9	17.5	7.6	7.2	7.3
August	120	12.0	0.3	10	0.3	4.4	5.0	3.8	1.3	0.9	23.2	18.4	7.5	7.3	7.4
September	105	8.0	0.27	8.2	0.2	4.6	5.8	4.4	1.9	1.3	19.0	16.5	7.5	7.3	7.4
October	86	11.0	0.3	7	0.27	5.2	5.7	4.9	2.0	1.4	17.3	16.0	7.5	7.3	7.4
November	93	9.0	0.3	7	0.2	5.0	5.5	4.6	1.7	1.2	19.0	14.2	7.5	7.2	7.4
December	90	10.0	0.3	7	0.27	5.2	5.8	5.0	1.7	1.2	20.8	19.1	7.5	7.2	7.4
January	88	10.0	0.25	7	0.26	5.3	5.6	5.1	1.3	1.1	20.9	16.9	7.5	7.2	7.4
February	101	10.6	0.18	8.3	0.31	5.3	5.5	5.1	1.6	1.6	20.5	17.0	7.5	7.3	7.5
March	89	9.7	0.17	7.4	0.24	5.3	5.8	4.1	2.5	1.4	22.8	14.0	7.6	7.3	7.4
April	94	11.2	0.18	7.8	0.28	4.2	4.9	4.2	2.6	1.8	21.5	15.3	7.6	7.2	7.5
May	92	9.6	0.11	7.6	0.24	4.6	5.2	4.6	2.2	1.7	20.5	19.2	7.7	7.1	7.4
June	97	12.5	0.1	8.1	0.2	3.6	4.3	3.6	2.9	2.1	22.6	21.1	7.6	7.2	7.4
July	88	14.0	0.1	7.4	0.35	2.7	3.2	2.6	1.8	1.7	23.8	20.3	7.6	7.2	7.5

Note R—Raw sewage. C. W.—Clear well.
C—Effluent clarifier. P. H.—Tap at make-up tank in power house.

Wash-water storage tank—This tank, which is used to store the wash water from the filters, is 25′ long by 16′ wide and 4½′ deep below the overflow. A small centrifugal pump returns the wash water to the pre-settling tank.

Pumping equipment—The final effluent from the plant is pumped through 1½ miles of 4″ pipe to a 200,000 gal. elevated tank by two 3-stage centrifugal pumps.

In Tables I, II, and III are given, respectively, the *B. coli* density in the reclaimed sewage for the years 1929 to 1933 inclusive, the monthly averages of chemical analyses, and data pertaining to the operation of the treatment plant for 1933 and up to August, 1934.

Handling reclaimed sewage—All the pipe lines carrying reclaimed sewage are enclosed in vitrified pipe and all pipes in buildings or above ground are painted red, and over every service outlet there is a sign warning against drinking the water. The tank in which the reclaimed sewage is stored is 125′ lower than the tank used for domestic water. Accurate maps of the 2 water systems are kept up to date. Beginning in October this year a dye solution strong enough to give a color to the reclaimed sewage will be added once

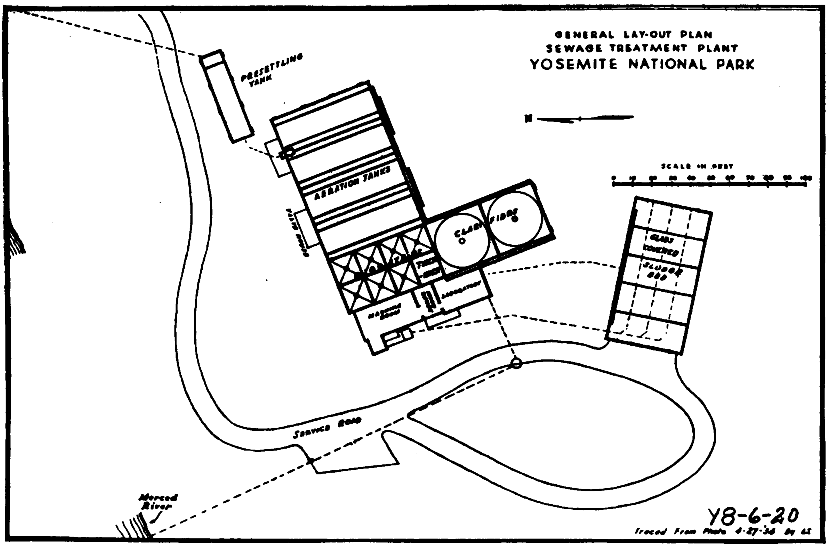

FIGURE II—Sewage Treatment Plant, Yosemite National Park

a month to the effluent at the treatment plant.

Uses of reclaimed sewage—The reclaimed sewage is used in locomotive boilers, boilers for heating purposes, for watering lawns and flowers at the El Tovar Hotel, for flushing toilets in public comfort stations, washing automobiles, cooling water in jackets of Diesel engines, and in pipes used for drying garbage in an incinerator.

Cost of reclaiming sewage—The cost of operating the treatment plant, exclusive of interest and depreciation, but including pumping the reclaimed sewage to the storage tank, averages approximately $0.38 per 1,000 gal.

ACTIVATED SLUDGE AND DISINFECTION

In 1930 there was constructed in Yosemite Valley in Yosemite National Park, an activated sludge plant[3,4] to replace an Imhoff tank and natural sand filters which were badly overloaded and producing offensive odors. Yosemite Valley, at the only place where a new sewage treatment plant could be located, is approximately 1 mile in width with vertical walls about 3,000′ in height, and there are two highways, one on each side of the river which flows through the valley. On account of the odor nuisance and bad appearance of the old treatment plant, and the unfavorable topography of the floor of the valley, with regard to suitable sites for a new plant, local sentiment in the valley was doubtful that any type of treatment plant would operate without some kind of nuisance. The stringent requirements which the new plant had to meet were (a) that there would be no odors, (b) that the plant could not be seen from the highways on the floor of the valley or on slopes leading out of the valley, (c) that there would be no noise, (d) that the Merced River, which is used as a source of domestic water supply, would not be contaminated, and (e) that fish in the river would not be killed by chlorine in the effluent.

The treatment plant was designed for a maximum of 1,200,000 gal. of sewage daily, which was approximately twice the maximum flow up to 1930. Practically all of the sewage is pumped to the plant at a rate of 850 gal. per minute, which, while the pumps are operating, gives a rate of flow of 1,200,000 gal.

TABLE III

OPERATING DATA SEWAGE TREATMENT PLANT, GRAND CANYON NATIONAL PARK

(Figures represent monthly averages of daily records)

Month 1933 1934	Sewage flow 1,000 gallons daily	Reclaimed sewage 1,000 gallons daily	Temp. deg. F.		Sludge wasted 1,000 gallons		Aeration tanks			Sand filters		Chlorine		
			Raw	Effl.	Raw	Active	Per cent sludge in tanks	Aeration hours	Cubic feet* air used per gal.	Rate† filtration m.g.d.	Per cent wash water	lbs.	p.p.m.	Resid. p.p.m.
January	76	75	70	62	0.6	0.2	23	10.2	4.0	23	6.7	2.7	5.6	0.8
February	68	67	70	61	0.6	0.3	25	10.3	4.4	21	7.4	3.1	6.0	0.8
March	69	68	76	66	0.6	0.3	24	10	4.3	21	7.3	3.7	6.7	
April	93	92	78	66	0.6	0.3	22	10	3.3	28	5.6	3.6	6.0	0.8
May	102	101	80	67	0.6	0.5	25	9.2	3.0	31	5.1	4.1	4.8	0.8
June	103	102	74	82	0.6	0.6	25	8.9	3.0	31	5.0	3.8	4.5	
July	105	104	86	78	0.6	0.4	24	8.8	2.9	32	6.2	4.6	6.0	1.0
August	112	103	84	78	0.6	0.8	25	8.7	2.7	34	5.8	5.	5.9	0.8
September	108	107	84	77	0.6	0.6	25	8.5	2.8	33	6.	4.6	6.	0.8
October	103	102	82	75	0.6	0.7	26	8.9	2.9	31	6.3	4.8	6.1	0.8
November	96	94	79	71	0.6	0.6	24	9.6	3.1	29	6.8	4.5	6.4	0.8
December	99	97	75	68	0.6	0.5	25	9.2	3.1	30	6.5	4.5	4.6	0.8
January	95	92	68	75	0.6	0.4	24	10	3.2	29	6.8	4.6	5.	0.8
February	96	92	84	72	0.6	0.7	25	9.9	3.3	29	6.8	5.3	6.5	0.8
March	101	100	72	79	0.6	0.8	21	9.7	3.	31	6.4	4.9	7.	0.7
April	109	107	85	77	0.6	1.2	29	8.1	2.8	33	5.9	7.4	6.9	.44
May	105	103	86	78	0.6	1.6	26	8.7	2.9	32	6.2	5.2	5.1	.52
June	112	110	89	80	0.6	1.0	27	8.2	2.7	34	5.8	5.6	6.	.43
July	110	109	93	86	0.6	0.8	27	8.3	2.8	33	5.9	6.1	6.7	.46

* Air supplied at a uniform rate of 225 c. f. m. No deduction for air lift.

† Average rates; maximum rates are approximately twice the averages.

through the plant. The general layout of the plant is shown in Figure II.

The plant has the following treatment devices and equipment:

Coarse screens — The screen chamber, which is 7½′ by 5′ by 2′ deep below the outlet, has two bar screens, one with 2″ and the other with 3″ openings. The screens were designed primarily to remove coarse material which might clog the 12″ siphon which begins at the screen chamber and extends under the river to the pre-settling tank.

Pre-settling tank — This tank is 40′ by 10′ by 16′ deep to the bottom of the hoppers, and has a concrete cover. The theoretical detention period is 45 minutes when treating 850 gal. per minute, the capacity of the pump normally used to lift the sewage to the gravity line to the treatment plant. There is a baffle at the inlet but only a skimming weir at the outlet. The sludge is drawn from the hoppers to the thickening tank daily during the period of maximum travel to the park.

Aeration tanks — There are 4 aeration tanks of the Manchester type, each 50′ by 18½′ and 12′ effective depth. There are in each tank, two rows of porous

TABLE IV

B. COLI IN EFFLUENT OF SEWAGE TREATMENT PLANT AND IN MERCED RIVER ABOVE AND BELOW OUTLET OF PLANT, YOSEMITE NATIONAL PARK PERIOD—JANUARY 1, 1932, TO AUGUST 4, 1934

SOURCE	Number of 10 c.c. portions tested for B. coli			Per cent 10 c.c. portions positive for B. coli			Number of 1 c.c. portions tested for B. coli			Per cent 1 c.c. portions positive for B. coli		
	1932	1933	1934	1932	1933	1934	1932	1933	1934	1932	1933	1934
Merced River 2 miles above treatment plant	251	186	155	63	38	17	39	50	31	36	34	6.5
Merced River 1 mile below treatment plant	263	192	155	62	40	22	38	52	31	37	30	13
Merced River * at park boundary	254	191	155	50	40	25	38	52	31	18	23	9.7
Effluent † treatment plant 8:30 A.M.	259	260	150	20	2.3	2.7	36	52	30	14	1.9	0.0
Effluent † treatment plant 10:00 A.M.	258	249	140	23	2.4	2.8	36	51	28	17	0.0	0.0
Effluent † treatment plant 11:30 A.M.	238	249	140	23	2.0	5.0	31	50	28	19	0.0	0.0

* Approximately 8.5 miles below treatment plant.
† After disinfection.

plates set over continuous channels extending the length of the tanks. The plates were set in recesses along the sides of the channels and on flat aluminum bars across the channels. Cement grout was used to hold the plates in place and make airtight joints. Air is applied at one end of the channels and at the opposite ends there are outlets for flushing them and washing the under surfaces of the plates. Tanks 1 and 2 are arranged for operation as single units, in series or in parallel, and tanks 3 and 4 in series with 1 and 2. The tanks were designed for a theoretical aeration period of 5½ hours with 20 per cent activated sludge.

Final clarifiers—The two clarifiers, each 28′ square at the top and with circular bottoms, have 11′ and 10′ effective depths, respectively, and are operated in series. Each tank was designed for a settling rate of 1,600 gal. sewage per sq. ft. per day and has an inlet baffle 5½′ deep. Sludge is drawn by air lifts from the first unit to the

FIGURE III—Yosemite National Park Sewage Treatment Plant Showing Machinery Room, Laboratory and Office Building and Glass Covered Sludge Bed

aeration tanks and from the second unit to the pre-settling tank. Liquid chlorine is applied to the influent to the second clarifier by full automatic chlorinators in duplicate.

Thickening tank—This tank is 12′ by 13′ by 13′ deep to the hopper bottom. Sludge is discharged into this tank by gravity from the pre-settling tank and the first clarifier. The concentrated sludge is pumped to the digestion tanks and the decanted liquor to the pre-settling tank.

Digestion tanks—There are 4 covered sludge digestion tanks, 3 of which are 28′ by 12′ by 18½′ deep to the bottom of the hoppers, and the fourth, 13′ by 12′ by 18½′. There are concrete domes for collecting gas, coils around the walls for heating the sludge, and a pump for delivering sludge to the tanks and for circulating the sludge. Digested sludge flows by gravity to the sludge drying bed.

Sludge drying beds — The glass covered sludge drying bed is divided into 5 sections, each 15′ by 40′ and has 1′ of river sand with underdrainage connected to a pipe line leading to a pump sump.

Drainage sump—The waste liquors from the digestion and thickening tank, drainage from sludge beds, the wastes from laboratory and toilets, and all other liquid wastes from the plant, other than the disinfected effluent, are discharged into the drainage sump and pumped to the pre-settling tank.

Blowers—There are two centrifugal blowers, each with a capacity of 425 cu. ft. free air per minute against a head of 7 lb. at an elevation of 3,000′.

Operation of treatment plant—The plant is under the direct supervision of two operators between 8 A.M. and 2 A.M., with no one at the plant from 2 A.M. to 8 A.M. In addition to operating the plant, the operators inspect and keep in working order the ventilating apparatus at the Wawona Tunnel, and one of the operators makes the chemical analyses of sewage and bacteriological analyses of samples from the effluent of the plant, and water and milk collected at various places in the park. Three samples of the effluent and 3 from the Merced River above and below the outlet of the plant are shipped to the U. S. Public Health Service Laboratory in San Francisco each week for bacteriological analysis. The treatment plant has been in continuous operation since August, 1931, and except for bulking of sludge in the aeration tanks at infrequent intervals, and minor troubles with the mechanical equipment, it has operated in a highly satisfactory manner. Figure III shows the laboratory and office building and glass covered sludge bed. Table IV gives the density of *B. coli* in the effluent of the treatment plant and in the Merced River above and below the outlet from the plant to the river.

On account of the many duties each operator has to perform at the treatment plant during his shift, it is necessary to limit the chemical analyses to those essential to the operation of the plant and to a knowledge of the character of the effluent discharged to the river. Table V gives operating data and the chemical analyses, except the suspended matter in the raw sewage which is determined only occasionally in composite samples collected on Sunday, which is the day of the week ordinarily with the heaviest travel to the park. The suspended matter in the sewage produced on Sundays averages between 100 and 125 p.p.m.

SETTLING TANKS AND DISINFECTION

Settling tanks with disinfection of the effluent, have been used for treating sewage at places in the parks where large rivers or lakes, which are not used as sources of domestic water supplies, are available for receiving the sewage. This type of plant is used at 7 places in Yellowstone Park where there are large hotels, lodges, and camp grounds. The design of the settling tank used is shown in Figure V.

A uniform amount of chlorine, which is sufficient to disinfect the sewage at the maximum rate of flow, is added continuously to the effluent of a settling tank as it is discharged through vitrified pipe to the bottom of a contact tank which has a detention period of approximately 15 minutes at the time of maximum flow of sewage through the tank.

An inspector visits these plants daily to test the effluent for free chlorine and adjust the chlorine dosage. In adjusting the flow of chlorine to the maximum rate of flow of sewage, there is a fairly high chlorine residual during the night, but it has never had any effect on fish in the streams receiving the sewage. An attempt is made to maintain a chlorine residual of not less than 0.5 p.p.m. at all times.

In the fall of the year all the sludge is either drawn off from the tanks by gravity to prepared beds, or it is pumped out by portable gas-engine-driven diaphragm pumps and the tanks emptied and cleaned.

SETTLING TANKS AND SPRAYING SYSTEMS

In many of the national parks there are hotels, lodges, and tourist camps located in places, usually in the mountains, where the topography and other local conditions are unfavorable for the location, construction, and operation of the commoner types of sewage treatment or disposal plants, and where it is much less expensive and often more satisfactory in many ways to treat the sewage in settling tanks and spray the effluent, disinfected when advisable, over natural ground surfaces, usually hillsides of porous material and covered with vegetation. This method of sewage disposal is generally used at areas

TABLE V

OPERATING DATA AND CHEMICAL ANALYSES, SEWAGE TREATMENT PLANT YOSEMITE NATIONAL PARK

Month 1933 1934	Sewage flow 1,000 gal. daily	Aeration tanks				D. O. final efflu-ent	B. O. D. effluent clarifiers p.p.m.		Sludge digestion tanks		Chlorine		
		Cu. ft. air per gal. sewage	Per cent settle-able solids	Per cent suspend-ed solids	pH efflu-ent	p.p.m.	first	second	pH	Temp. deg. F.	lb. per day	p.p.m.	Resid. p.p.m.
Jan.	73	10.	18	0.22	6.5	9.4	6.6	0.6	7.1	63	19	31	1.9
Feb.	62	8.7	23	0.24	6.5	10.9	4.2	1.4	7.1	58	9.3	18	1.8
Mar.	84	5.8	24	0.19	6.8	10.5	4.3	2.1	7.2	59	9.0	13	1.8
Apr.	207	2.6	21	0.19	6.2	9.7	4.3	2.0	7.2	65	12	6.9	2.0
May	272	1.7	20	0.19	6.3	9.1	3.8	1.0	7.2	67	16	7.1	2.1
June	661	1.7	19	0.21	6.1	6.3	5.1	2.0	7.1	64	40	7.3	1.8
July	665	1.9	20	0.23	6.0	4.3		1.3	7.1	66	65	12	1.8
Aug.	540	2.7	23	0.21	5.9	6.1	4.4	0.9	7.4	75	39	12	2.0
Sept.	363	2.0	23	0.22	6.2	6.5	4.6	0.9	7.3	75	24	7.9	2.3
Oct.	233	3.1		0.17	6.3		5.8		7.3	84	12	6.3	2.1
Nov.	164	4.1	12	0.10	6.6	8.7	5.2	1.3	7.2	80	10	7.3	2.7
Dec.	161	3.3	11	0.12	6.4	8.9	4.9	1.1	7.3	73	8.6	6.4	1.8
Jan.	186	3.3	11	0.11	5.8	8.7	5.7	0.9	7.2	71	13	8.4	
Feb.	189	3.3	12	0.11	5.9	9.0	6.0	1.4	7.2	72	12	7.8	
Mar.	254	2.4	9.5	0.08	6.1	9.4	5.7	1.4	7.4	68	12	5.5	
Apr.	360	1.5	11	0.10	6.2	8.3	6.5	1.4	7.3	75	15	5.1	2.1
May	537	1.7	8.7	0.11	6.0	7.2	6.8	1.8	7.4	75	33	7.3	
June	645	1.9	13	0.13	5.8	6.2	5.7	1.2	7.1	70	72	13	2.4

Note: Figures in table represent averages of daily records.

which are open to visitors only during the warmer seasons, and when there is little rainfall. There are 10 of these plants in the parks, with disinfection of the effluent at 3. Typical examples of this type of treatment plant are at Giant Forest and Lodgepole Camp in Sequoia National Park.

At Giant Forest, with a population of approximately 1,000 during the summer, the sewage is treated in a settling tank and the effluent applied by a siphon to sprays which are set in a pipe line approximately 800′ long and operate under a head of approximately 50′. Below the sprays there is a heavy growth of trees and shrubbery and the soil for a depth of 2′ is porous. The spraying system is located where the drainage area above is small and where the nearest stream below is approximately 1 mile away. The loose material and the vegetation absorb practically all of the effluent and no sewage has ever been found flowing over the ground at a distance of more than 500′ below the sprays. This plant has been operated during the summer and fall months for 7 years. There is a slight odor of fresh sewage at the settling tank and where the sewage is sprayed over the hillside, but it cannot be detected 100′ from the disposal plant. The absence of an odor nuisance at this and at most of the plants is due no doubt to the fact that the sewage is unusually fresh when it reaches them and that there is little decomposition in the settling tanks.

At the Lodgepole Camp, the sewage from an automobile tourist camp with a population of approximately 300, and a government utility area with 25 employees, is treated in a settling tank and the effluent, disinfected with chlorine, is applied by alternating siphons to sprays set on 2 separate pipe lines each 300′ long and approximately 15′ below the siphons. There are trees and shrubbery below the sprays and the soil is sandy and loose. The effluent is disinfected to protect a stream which receives drainage from the area where the sewage is sprayed.

The areas used for the spraying systems at the different plants are selected where there is little drainage above and where the sewage will be sprayed over ground having no well defined depressions or channels. Whenever the sewage begins to flow in channels the adjacent sprays are closed and the ground is allowed to dry, and the soil raked. The design of the spraying system is shown in Figure IV.

SETTLING TANKS AND SUBSURFACE GALLERIES

In many areas where there are accommodations for a comparatively small number of visitors and where it is advisable for various reasons to have the sewage disposal system entirely below the surface of the ground, settling tanks and subsurface galleries are used. In these areas careful investigations are made to find suitable porous material, such as gravel or coarse sand.

The settling tanks, which are used from 4 to 6 months in the year, are cleaned each fall. These are designed for a capacity equal to the largest volume of sewage produced daily, with approximately an additional one-third capacity for storage of sludge. All the settling tanks which have been constructed have been designed on the above basis, and all of them are cleaned once a year. The filter galleries are open at the bottom and the covers consist of either concrete, redwood, or half-round corrugated galvanized iron. The half-round culvert pipe can be obtained in diameters ranging from 8″ to 86″. The length and width of gallery used in any particular case depends on the volume of sewage treated and the character of the subsoil. A typical disposal

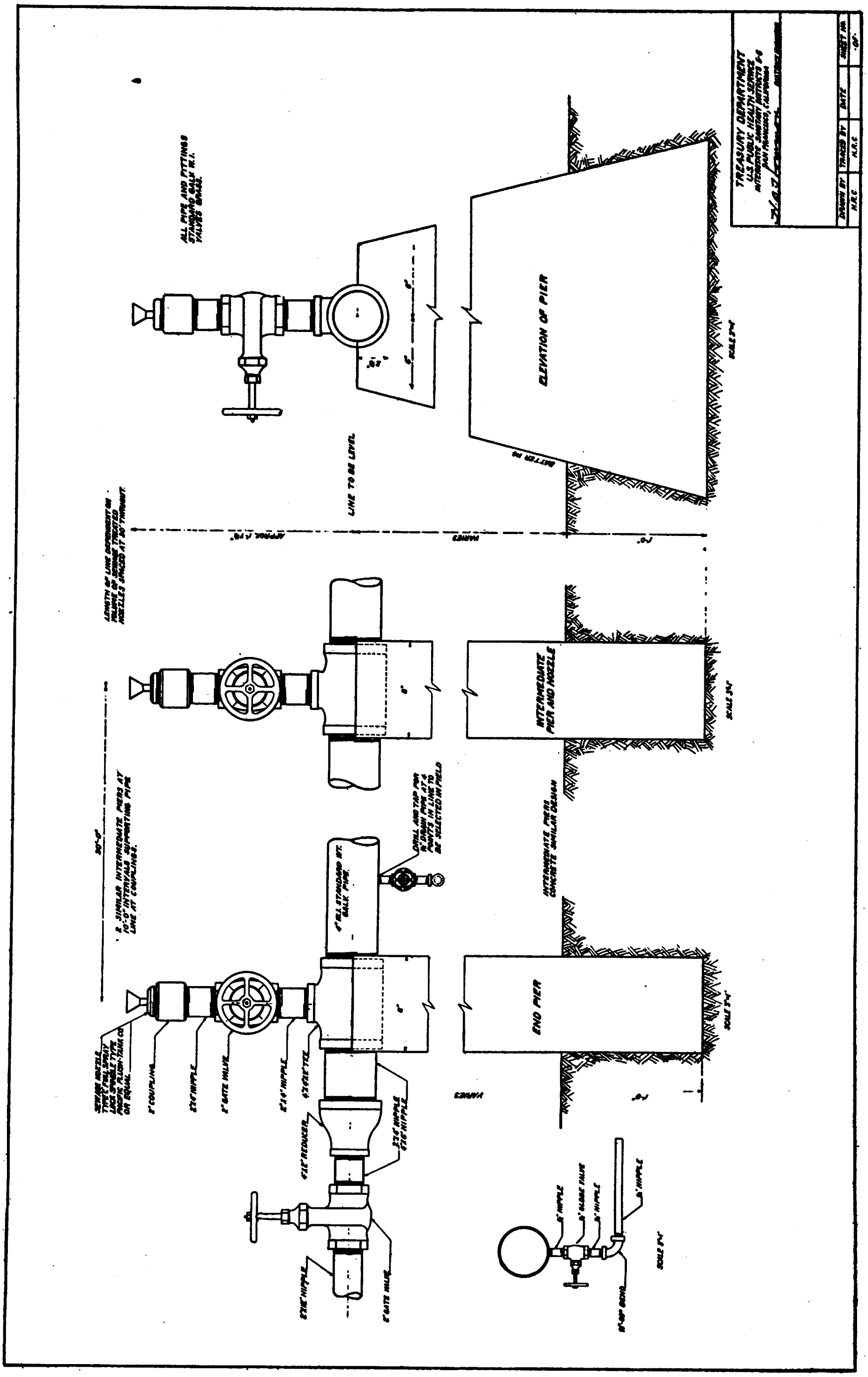

FIGURE IV—Standard Design Sewage Spraying System

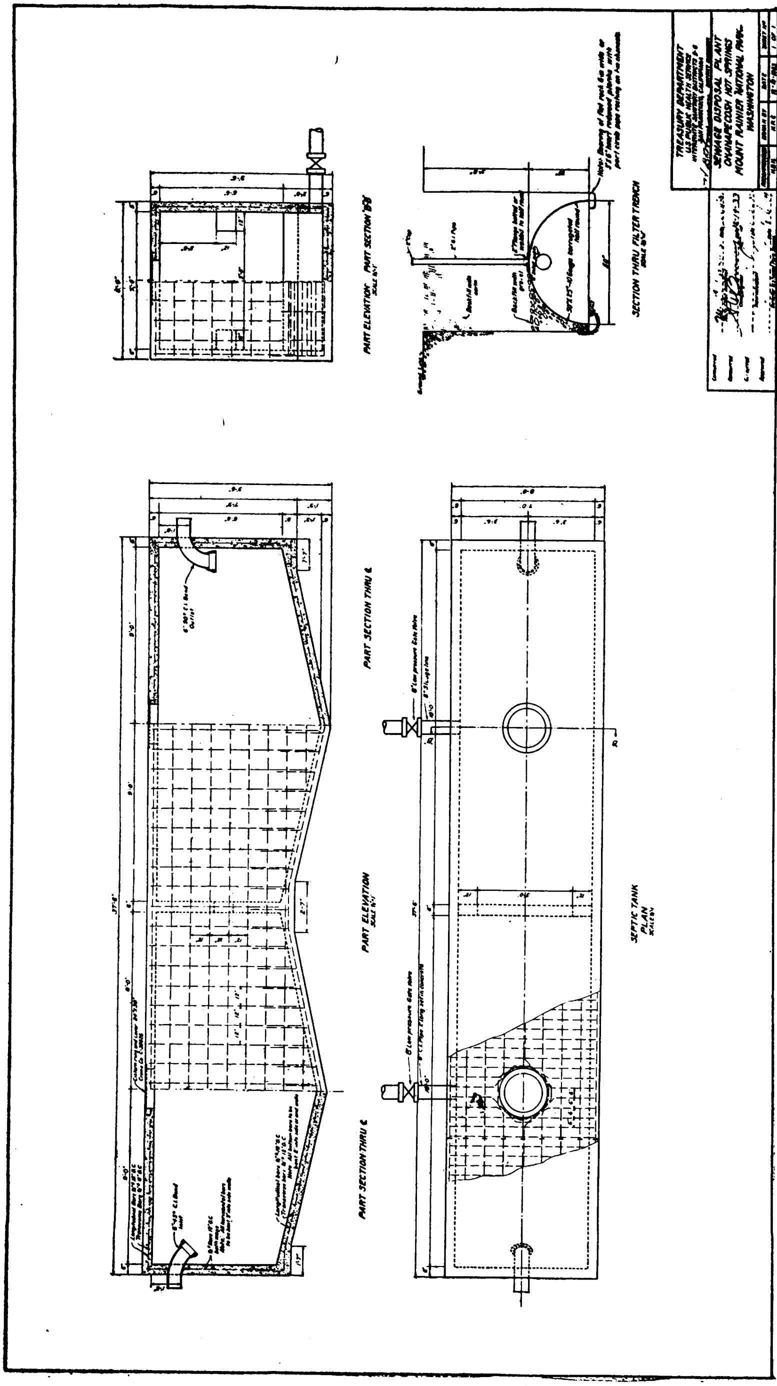

FIGURE V—Settling Tank and Sub-surface Gallery plant of this type was constructed at Zion National Park to take care of the sewage from the headquarters area, housekeeping cabins, and automobile camp. In this area the only available site for a disposal plant is near the cabins, camp, and grounds used by visitors, and it was not advisable to have a sewage disposal plant above the ground. A design of a typical settling tank and subsurface gallery is shown in Figure V.

The effluent from the tank is piped to a diversion box from which it is discharged into 3 subsurface galleries each 100′ in length and 5′ in diameter. The subsoil is loose gravel and rock. The tank is covered with 2′ of earth and the galleries are 5′ below the surface.

There are 14 disposal plants of this type in the parks and all of them are operating satisfactorily. The main considerations which govern the successful operation of this type of plant are adequate storage for sludge and low settling rate in the settling tanks, porous subsoil, and sufficient area in the galleries.

SETTLING TANKS AND GLASS COVERED SAND FILTER

On account of unfavorable local conditions, particularly limited space, impervious subsoil and winter temperatures as low as —35° F., a septic tank and a covered intermittent slow sand filter, divided into 2 beds, were constructed in 1926 to dispose of the sewage from approximately 50 employees and their families in summer and 30 in winter, at the government utility area in Rocky Mountain National Park. The roof over the sand filter consists of wood with glass on the side exposed to the sun in winter. A general view of the sand filter is shown in Figure VI.

The effluent from the septic tank is applied to the sand filter by an automatic siphon. No difficulties have been experienced in operating the filter in the winter with temperatures below zero for weeks at a time.

SETTLING TANKS AND OPEN TRENCHES

Settling tanks and open trenches in porous soil have been found a practical method of sewage disposal in several places, particularly where there is a comparatively small volume of sewage produced and trenches can be dug in porous soil in areas not frequented by visitors and where other methods of disposal are not practicable. The trenches are usually 2′ in depth and 2′ wide at the bottom, and at intervals of 100′ there are dykes across the trench with pipes connecting the different sections. Disposal plants of this type are operated only during the summer season. A dense growth of algae develops in the sewage in the trenches and there are no odors noticeable 50′ away. Each spring about ½″ of surface material is removed from the trenches. This method of disposal is inexpensive, and where local conditions are favorable is a very satisfactory method of getting rid of sewage without danger of contaminating streams.

SETTLING TANKS, BROAD IRRIGATION, PONDS AND DISINFECTION

At the Mammoth Hot Springs area in Yellowstone Park there are housekeeping cabins, hotel, lodge, automobile tourist camp, general stores, with a

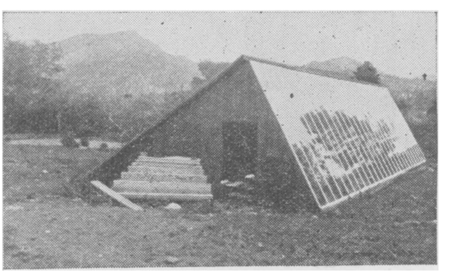

FIGURE VI—Glass Covered Sand Filter, Rocky Mountain National Park permanent population consisting of employees of the government and public operators. This area is adjacent to the Gardiner River which is the emergency source of water supply for the town of Gardiner located on the river about 6 miles below the headquarters area. The population of the Mammoth Hot Springs area during the summer is approximately 1,250, and the permanent population during the winter averages about 125.

Two different methods of sewage disposal were considered for the Mammoth Hot Springs area. One included settling tanks, sprinkling filters, and disinfection of the final effluent which would be discharged into the Gardiner River, and the other included a settling tank and disinfection of the effluent which would be disposed or by broad irrigation, ponding, and disinfection of whatever sewage might overflow from the ponds. The latter method was adopted since it offered a greater measure of protection of the river against contamination, and the topography of the ground was favorable for this method of disposal. The component parts of the disposal system include settling tank, 3 chlorinators, broad irrigation, and ponds. One of the chlorinators is located at the headquarters area and is used to disinfect the small volume of raw sewage produced during the winter when the disposal plant is inaccessible on account of deep snow, and the other 2, one of which is used to disinfect the effluent from the settling tank and the other the overflow from the ponds, are operated during the summer and fall.

The effluent from the settling tank, during the time when the park is open to visitors and a large volume of sewage is produced, is discharged into open ditches which carry the sewage to the areas used for broad irrigation and to the ponds. During the winter the effluent from the settling tank does not overflow the ditches and ponds, and broad irrigation is not necessary. A small amount of sewage which flows out of the ponds during the summer is discharged onto a sand bar and no doubt eventually reaches the river, but since it has been treated twice with chlorine and stored several days in ponds it is not believed the small amount of overflow from the ponds seriously contaminates the river water. An inspector visits the disposal system daily to adjust the flow of chlorine and regulate the flow of sewage to the areas under irrigation and to the ponds.

There is a slight odor of fresh sewage at the settling tank and a swampy odor near the ponds.

A few bacteriological analyses of samples collected during the summer from the overflow from the ponds before final disinfection showed that the *B. coli* group of organisms was present only occasionally in 1 c.c. portions.

This disposal plant was inexpensive to construct, costs only a small amount to supervise and maintain, and has produced very satisfactory results.

SUMMARY

The uniform policy followed with regard to the disposal of sewage in the national parks has been to avoid contaminating streams or interfering in any way with the use of streams for fishing or recreation, and to locate, construct, and operate treatment and disposal plants so that they will not only be free of odors and any other nuisance, but will conform to the high standards of the Park Service in relation to architecture and preservation of the natural scenery in the parks.

ACKNOWLEDGMENTS

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tors, respectively, of the treatment plants at the Grand Canyon and Yosemite National Parks, for data furnished regarding the operation of these plants.

REFERENCES

1. Hommon, H. B. Sewage Treatment Plant at the Grand Canyon National Park. *Reprint No. 1249* from *Pub. Health Rep.*, Oct. 5, 1928. U. S. Government Printing Office, Washington, D. C.

2. Hall, Hillard. Grand Canyon Activated Sludge Plant. *California Sewage Works J.*, V, 1, 1932–1933.

3. Hommon, H. B. Yosemite Valley Activated Sludge Plant. *California Sewage Works J.*, IV, 1, 1931.

4. White, Russell C. Operation of Yosemite Valley Activated Sludge Sewage Treatment Plant. *California Sewage Works J.*, V, 1, 1932–1933.

DISCUSSION

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MR. Hommon's paper is of particular interest to me because, in 1921, I had the privilege of assisting him when he inaugurated the present system of controlling sanitary conditions in our national recreation areas. Three years of work in the western group of parks gave me a comprehensive picture of the magnitude of this task and of the peculiar difficulties which had to be overcome. In 1923, I was directed to return to the east and, about 1930, due to constantly increasing National Park Service activities in the eastern section of the country, Eastern and Western Divisions were established. Supervision of sanitation in the Eastern Division, which included all areas east of the Mississippi River and, in addition, Hot Springs National Park in Arkansas, was lodged in my office. I continued in charge of this work until 1934.

In 1921, in what is now the Eastern Division, the National Park Service administered only 2 areas, Acadia National Park in Maine, and Hot Springs National Park in Arkansas. I believe that very few people realize to what extent the number of national recreational, monumental, and historical areas under the careful supervision of that service has increased. Contrasted with the 2 areas in 1921, a summary this year shows the following:

TABLE I

National Parks	5	
National Historical Parks	1	
National Monuments	9	
National Military Parks	11	
Battlefield Sites	10	
Miscellaneous Memorials	4	
National Cemeteries	11	51
National Parks (proposed) (Mammoth Cave, Shenandoah and Everglades)	3	
National Monuments (proposed)	2	5
National Capitol Parks		1
		57

These areas are not concentrated in any one section, but are well distributed throughout the East. Their geographical distribution is shown in Table II.

In the 2 older areas, Acadia and Hot Springs, sanitation has kept pace with the growth of the parks. Because of the importance of federal activities in the city of Hot Springs, the National Park Service is contributing generously to sewerage extensions and improvements and to new sewage disposal plants. The federal government's investment in those works has justified a controlling interest by the National Park Service in the selection of the designers and in the methods, efficiency, and continuity of plant operation. These interests are safeguarded in a